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PECULIARITIES OF CONSTRUCTION AND SERVICE OF TANK RVS-200 FOR STORAGE OF DIESEL FUEL IN ANTARCTICA AT THE STATION «AKADEMIK VERNADSKY»

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The analysis of materials of expert inspection of the welded tank RVS-200 for diesel fuel at the Ukrainian Antarctic Station «Akademik Vernadsky», made by the SE «Experimental Design and Technological Bureau of the E.O. Paton Electric Welding Institute of the NASU», is given. It was shown that according to the region of its location, the tank of only 200 m^3 capacity is transferred to the highest criticality class CC3 with the fixed service life of not less than 40 years. Under these conditions the requirements to ecological purity of the object and the environment, at a complete isolation and limited capabilities of repair, predetermine the need in extraordinary constructive solutions on providing the maintenance-free service life. The specific technical solutions of the considered problem are given. 7 Ref., 5 Figures.

Keywords: *welded tank, highest criticality class CC3, corrosion damages, austenitic stainless steel, corrosion protection*

In 2007, at the Ukrainian Antarctic Station «Akademik Vernadsky» on Galindez Island in the archipelago of the Argentine Islands (Antarctica) the welded cylindrical tank RVS-200 for storage of diesel fuel was constructed (Figure 1). The project of the tank was developed by the OJSC «UkrNIIproektstalkonstruktsiya», the metal structures were manufactured and assembled by the LLC «Kirovograd Plant of Technological Equipment». The natural conditions at the construction region are quite favorable for the vessel service. The climate is maritime, subantarctic, the minimum temperature over the years of observations has been not lower than –8 °C. However, the data about the minimum temperature of –47 °C in winter are available (the bulletin «Around the World», Ukraine, 2010, Issue 11). The wind is 30–35 m/s, the snow is 300 days in a year.

The requirement to the tank construction is contained in the memorandum of 20.07.1996 about the transfer of station «Faraday» by England to Ukraine, (at present, the station «Akademik Vernadsky»). Somewhat earlier, in 1992 Ukraine acceded to the Antarctic Treaty, which contains the specific requirements to preservation of the ecological environment in Antarctica. Until that time, at the station «Faraday» the English specialists constructed two vessels for storage of liquid fuel. The main vessel is in the form of rectangle in design of about 6 m height. At the station «Akademik Vernadsky» the vessel has been successfully operated for over 20 years as well. The design of vessel is simple and the adopted simplicity guarantees its complete safety at the absence of repairs for more than 50 years. The spatial system with vertical and horizontal posts and cross-bars, lined with sheets of austenitic stainless steel class of 6 mm thick from inside, is assembled of steel girders on bolted joints. The sheets are fixed to the frame using bolts through sealing gaskets. In the wall and roof there are techno-

Figure 1. General view of the tank RVS-200 at the Antarctic station «Akademik Vernadsky»

logical branch pipes and hatches for pumping in and out the fuel and inspection of its structure. Let us note that for the period of designing the considered tank, in Ukraine there were no state regulations regarding the system of providing the reliability and safety of construction objects. In the first edition the listed regulations of Ukraine were adopted in 2009 [1].

The project of the newly constructed tank was fulfilled in accordance with the requirements of Ukrainian standards VBN V.2.2-58.2–94. These standards are applied to the tanks for storage of oil and oil products, which are constructed at the territory of Ukraine. The increased ecological safety of the tank is provided by applying the design of the «glass in glass» type. These are two welded steel tanks, where each has its wall, bottom and roof. The geometrical dimensions of the tank are the following: the inner (main) tank: the wall height is 5.96 m, the inner diameter is 6.63 m; the outer (protective) tank: the wall height is 6.58 m, the inner diameter is 6.96 m. The distance between the walls is 160 mm. The material of all the structures is steel VSt5ps. The thickness of wall and bottom of the main tank is 5 mm. The thickness of wall of the protective tank is 5 mm and 8 mm of the bottom. The inner tank is designed for permanent storage of diesel fuel. The outer tank is an emergency one. If the impermeability of the wall or bottom of the main tank is violated the outer tank should localize the spilling of diesel fuel within its range. After that, from the outer tank the fuel should be pumped over to the spare vessel, the entire tank should be transferred to the fire works with the possibility of human staying inside the vessel, detection of damages and their causes and performing the necessary repair. After the hydraulic test according to the established procedure, the double-walled tank is commissioned for the further storage of diesel fuel. The accepted scheme of restoration of working serviceability of the considered tank is based on the availability of the serviceable product pipeline for pumping over the diesel fuel into the spare tank. The corrosion protection is provided by thickening the bottom of the outer tank to 8 mm and applying the protective coating resistant to diesel fuel to the bottom and the lower girth of wall of the main tank. The applying of sand blasting to the surface of the wall and the bottom and deposition of more resistant coatings were not considered by the project. During construction of the tank the following deviations from the project were admitted: two manhole-hatches of 500 mm diameter in the lower girth of wall were not assembled and the changes in the scheme of fuel supply to the vessel were introduced.

Figure 2. General view of basement arrangement of the tank RVS-200

After 10 years of service, in accordance with the Ukrainian standard [2], in January-March, 2016 the SE «Experimental Design and Technological Bureau of the E.O. Paton Electric Welding Institute of the NASU» on a contract base with the National Antarctic Scientific Centre of Ukraine, carried out the full technical diagnostics of the considered tank RVS-200.

The aim of the work was:

● basing on the results obtained at the full inspection of the tank using instrumental and calculation means, to prepare the conclusions regarding the compliance of the structures and serviceability of the tank RVS-200 with the standards of Ukraine [3; 4];

● to develop the definite proposals on bringing the tank RVS-200 to state in compliance with the requirements of effective standards regarding reliability and structural security.

The results of technical diagnostics are described in detail in the report of the agreement [5], and in the publication [6].

Basement of the tank. The tank was constructed on the monolithic rocky foundation which represents a characteristic surface of Galindez Island. The basement of the tank was made as a two-tier system of girders (Figure 2). The lower tier is composed of seven parallel reinforced concrete girders of 650 mm height, 460 mm width in the lower and 330 mm in the upper part. The girders are fixed to the basement with anchors. The anchors are fixed in the boreholes drilled in the rock and welded-on to the girders reinforcement. The distance between the girders in the axes is 1.20 m. The upper tier of the girders is composed of 15 steel girders (double-T No.14), which are welded-on to the embedded parts on the upper surface of the lower girders. The distance between the girders in the axes is about 0.41 m. The bottom of the outer tank leans against the upper girders. According to the project, on the bottom of the outer tank the wooden girders are laid (the bars of 100×100 mm cross-section) at 300 mm pitch. The lower bottom at the top and the bottom as well as wooden and steel girders are not available for visual inspection and instrumental control. The bottom of the main tank lies on the wooden girders. The existing design of the tank basement virtually eliminates the subsidence of the outer and inner bottoms of the tank. According to the measurements, the maximum deviation of the outer and inner contour of the bottom is equal to 6 mm. There are remarks concerning small repair of the reinforced concrete girders and annual inspection and works on preventing corrosion of reinforcement of the lower girders, steel anchors and upper tier girders.

Technical state of the outer tank. *Wall of the outer tank.* The wall is assembled of separate 3.0×1.5 m sheets of 5 mm thickness, previously rolled for the radius of the tank, which corresponds to the project. The size of a sheet was in many respects dictated by the conditions of its transportation, especially from the ship to the berth of the base, unloading on the berth and assembly applying the available mechanisms. The deviation of the wall from the vertical amounts to +22 mm outside and –26 mm inside, which does not exceed the standard tolerances. All welded joints are produced outside without backup welding of weld root which is explained by the assembly of the outer wall after the assembly of the inner one. The inspection and measurements of welded joints showed the good state of welds [5]. At the designed thickness of the wall being 5 mm and a three-fold safety margin, according to the calculated circumferential stresses, the one-sided welding provides a sufficient strength of vertical and horizontal welds. It is also important that the outer wall is loaded only in case of emergency, when the integrity of the inner (main) tank is violated. This eliminates its cyclic loading. The deviations from the standards existing in the welds, do not affect the serviceability of welded joints.

Bottom of the outer tank. The evaluation of the bottom was performed from the results of inspection and measurements of thickness of the projecting part of bottom (edges). The thickness of bottom is equal to 7.5–7.8 mm. To the bottom the branch pipe is welded-in for draining the condensate from the space between the walls. The branch pipe is brought outside the space between the reinforced concrete girders and ended with a valve. According to the data of the work [5] the lower bottom is serviceable.

The calculation for the static strength of wall of the outer tank showed that the estimated stresses in the first (at the bottom) and second girths amount to 45 and 35 MPa, which is 4–5 times lower than the allowable values for steel VSt5ps equal to 147 and 171 MPa [5]. The calculation confirms that the thicknesses are accepted as-designed as the minimum ones acceptable according to the standards for the given vessel. Let us note that under the load the outer tank can be only during its hydraulic testing and at the damage of the main (inner) tank with leakage of the stored diesel fuel from it. The state of the wall meets the project requirements.

Technical state of the inner (main) tank. The inner tank is intended for permanent storage of diesel fuel. Accordingly, the pipeline for pumping out diesel fuel from the tank is welded-in to its wall and the breathing fitting-valves are mounted on the roof. The inner surface of the bottom and wall contact constantly the stored product. The hatches in the lower girth for access to the inside of the tank for inspection of structures by technical personnel are absent. The access to the tank is only possible through the upper sky-light and vertical step-ladder near the wall. Let us note that when there are no opened hatches the human staying in the tank is prohibited.

Wall of the inner tank. The wall is assembled of separate sheets previously rolled similarly to the outer wall. The geometric shape of the wall meets the requirements of standards. On the surface the dents and convexities are absent. The deviation of generatrixes from the vertical amounts to +38 and –31 mm, the difference of marks of the outer contour does not exceed 6 mm [5]. The vertical and horizontal welded joints are produced by two-sided butt welds with full penetration. The detected individual deviations in the shape of weld beads, undercuts and displacements of edges to 1 mm (Figure 3) do not affect the serviceability of welded joints. The 5 mm wall thickness is appointed from the condition of minimum normative admissible thickness for the given vessel, which is confirmed by calculations of the outer tank [5].

Bottom of the tank. The bottom of the inner tank is manufactured of separate sheets. At first the sheets

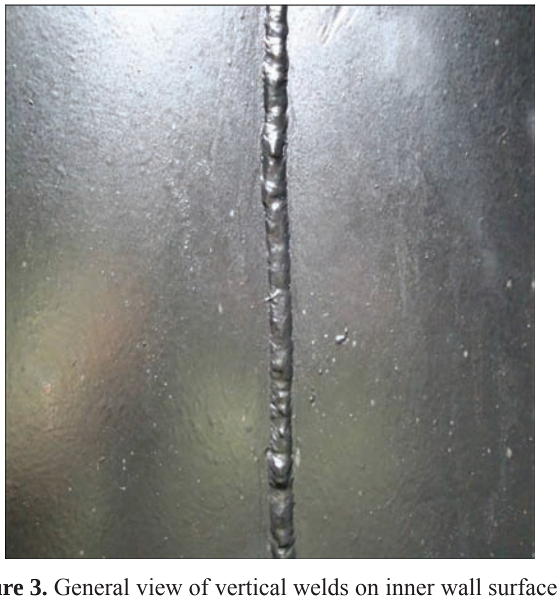

Figure 3. General view of vertical welds on inner wall surface of the main tank

were welded into five dimensional bands considering the tank diameter. After producing the transverse welds on the upper side, the bands were tilted and the welds were made on the rear side. At the 5 mm thickness of the bottom, the accepted technology provided impermeability of welds. Then, the dimensional bands were tightened on the bars with overlapping along the long sides and joined between each other by overlap welding. It can be assumed that according to this technology the lower bottom was manufactured as well. The performed visual inspection of the entire bottom surface and the vacuum control of all welded joints confirmed the impermeability of the bottom. In more detail, the technical state of bottom is described in [6]. At the bottom there is a branch pipe of the system for removal of under-product water and cleaning the tank. The branch pipe passes through two bottoms to the space between the reinforced concrete girders and ends with the valve.

Roof of the tank. Each tank (outer and inner) has its welded conical girder roof. Between the roofs the clearance is about 300 mm. Each roof was assembled of two shields on the ground. The flooring of each roof around the perimeter is welded-on by continuous weld to the fringing angle piece on the outer and inner wall. The flooring thickness is equal to 4 mm, which corresponds to the project. All branch pipes of hatches and valves pass through the flooring of both roofs being welded-on to them around the contour. The general view of the tank roof is shown in Figure 4. On the surface of roof there are no unacceptable defects in form of deflections and fractures under snow load. The surface of the existing separate dents, with the absence of paint layer on them, is exposed to shallow atmospheric corrosion of 0.2–0.3 mm depth. The state of the roof is serviceable.

Corrosion damages of the tank. At the general good technical state of metal structures of the considered tank (static strength and stability), the reliability of the tank is determined by the value of corrosion damages of main load-carrying structures. The performed diagnostics of the tank showed that the most affected by corrosion are the bottom of the inner tank and the lower inner surface of its wall to the height of up to 300 mm. This is the zone of accumulation of sludge water and different salt deposits: sulfides, chlorides, etc. The certain areas of the bottom, mostly those adjacent to the welds, have extended pit corrosion damages. The pit corrosion damages are concentrated as the regions of 10–20 cm^2 at the depth of 2.0 mm. A damage of the wall adjacent to bottom has a more uniform character with the depth of pits up to 1–1.5 mm. The available corrosion damages indicate that the surface state of the main bottom and lower part of the inner wall will determine the estimated service life of the tank. At the same time it should be taken into account that when there are corrosion damages at separate places going to the depth of 50 % from the thickness and more, the bottom is subjected to replacement [7].

Figure 4. General view of roof of the tank RVS-200

Search for an optimal variant of corrosion protection of tank RVS-200 under the conditions of Antarctica. According to the classification of standards of Ukraine [1], the given tank RVS-200 with diesel fuel at its location in Antarctica, belongs to the criticality category CC3 as a biologically hazardous object. The service life of such tank should be at least 40 years. The accepted life in this case has also another justification. A very high cost for delivery of structures and manpower to the site area, the absence of any in-site repair facilities and requirements to trouble-free service of the tank dictate also the need in the maximum long-term service life. Under the normal conditions on the «mainland» this is achieved by application of epoxy based coatings, plasma spraying of zinc, basalt coating and a number of other. All the abovementioned coatings require cleaning of surface up to steel glittering by the class Sa 3 according to ISO 8501.

In view of small volumes of works, the delivery of equipment set, sand, coating components and workers to Antarctica and back will exceed the cost of the tank itself. As was repeatedly testified in Ukraine and in other countries, the actual service life of the mentioned coatings does not exceed 12 years (at the standard life of 10 years [4]).

In view of the already passed 10 years of the tank service, to achieve the life of 40 years, it would be necessary to renew the coating three times, performing its sand blasting each time. The logical conclusion follows, that under such conditions an extraordinary solution for increase in service life of the tank and a fundamentally different approach to guarantee the required life are needed.

As one of the variants, the arrangement of a new bottom with the wall of up to 400 mm height on the bottom of the inner tank is proposed (Figure 5). The bottom and wall should be made welded of sheets of austenitic stainless steel of 3 mm thickness. The sheets of optimal sizes should be stacked and welded on the existing bottom without any special cleaning. Then the assembly and welding of sheets of the wall are performed between each other and along the entire upper perimeter to the wall of the inner tank. All the works should be carried out according to the project. In fact, a full impermeable lining of the lower surface of the main tank will be performed, which is subjected to active corrosion. The proposed solution ensures maintenance-free period of serviceability of the bottom for at least 40 years.

Conclusions

1. The project of the tank RVS-200 and its construction were performed without full consideration of characteristics of location and long-term service of the tank at the station «Akademik Vernadsky». The implementation of conclusions and recommendations on the further service of the tank, stated in the report [5] and in the present publication, will provide the required reliability in its service.

2. The technical state of the tank RVS-200 at the time of inspection meets the requirements of the Ukrainian standards VBN V.2.2-58.2–94 regarding the static strength and stability, on the basis of which the project and construction were completed. The inner (main) tank has unacceptable corrosion damages of the bottom which requires the fulfillment of solutions on corrosion protection of the bottom and lower part of its wall within 2–3 years, taking into account the estimated service life equal to 40 years. We consider that one of such solutions, which are proposed in this publication, the arrangement of an additional protective bottom and a part of the wall of austenitic stainless steel can be.

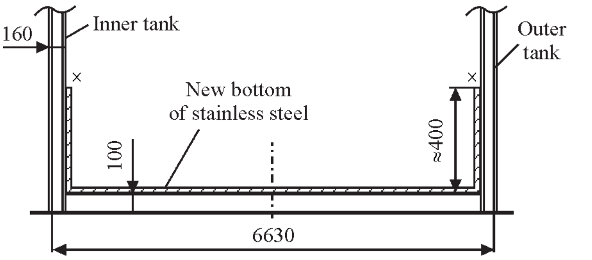

Figure 5. Scheme of constructive solution for protection of the inner bottom against corrosion

3. The deviations from the project, made during the construction of the tank RVS-200, do not allow performing its maintenance in the period of the service keeping the accepted safety regulations. Over the next 2–3 years it is necessary to bring the tank in compliance with the requirements of the project.

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